Design and Simulation of LTE Radio System for Broadband Wireless Access in Central Phnom Penh

Siren Seven
Telkom University
National Polytechnic Institute of Cambodia
Bandung, Indonesia
Phnom Penh, Cambodia
sevensiren7@gmail.com

Rina Pudji Astuti
School of Electrical Engineering,
Telkom University
Bandung, Indonesia
rinapudjiastuti@telkomuniversity.ac.id

Budi Prasetya
School of Electrical Engineering,
Telkom University
Bandung, Indonesia
budiprasetya@telkomuniversity.ac.id

Abstract—The most up-to-date application and many numbers of users need higher access speeds and lower latency of wireless communication. As a result, mobile companies need more capacity and higher efficiency to give the high quality service to the customers. LTE has been designed to get broader channels up to 20MHz, with low latency and packet optimized radio access technology. The peak data rate envisaged for LTE is 100 Mbps in downlink and 50 Mbps in the uplink. To support the simultaneous use of legacy and new systems, mobile companies need to give a better radio system, especially in central Phnom Penh city of Cambodia. The purpose of this study aims to designs, simulates, analyzes and expose the state of the art of map planning LTE radio system. Special focus is laid on radio link budget along with broad coverage area and capacity. The outcomes cover the interference limited coverage calculation, the traffic capacity calculation and radio frequency assignment. The implementation is attained on the software platform for the LTE Radio Planning and also can see the simulation antenna in Google Earth. The study will show a detailed LTE radio dimensioning procedure such as coverage area and capacity in Phnom Penh city. The simulation and analysis of the coverage by signal level and overlapping zone also a part of this work.

Keywords— Long Term Evolution; MIMO; Coverage area; Capacity; Cost 231-Hata.

I. Introduction

The capital city, Phnom Penh has become the main hub of country's economic and industrial activities and also the center of security, politics, tourism, cultural heritage, as well as diplomacy. Currently there are two wireless communication systems operated by GSM and UMTS in Phnom Penh city. Both systems still work separately in different technique and also different environment. So the speed, data rate and service still not good for the newer technology device. The future system will support many demanding applications such as interactive TV, mobile video blogging, and advanced gaming. We need to use the better broadband wireless communication systems in central Phnom Penh.

All the wireless technology companies target the users by providing the high Quality of Service (QoS) and customer satisfaction. Theoretical limits set the targets that are hard to accomplish in real scenario as there are multiple factors to consider in the practical case; environment, fading, reflections, noise etc., particularly for the users whose position is mobile, the situation becomes different. The intention of the new concept is that, LTE system can be used or accessed in the central Phnom Penh. Taking the above mentioned situation for consideration, this paper aim to explore and describe state of the art of design and simulation of LTE radio system for broadband wireless access in the city. Moreover, it also includes the radio planning in LTE including the network coverage and capacity, frequency planning, methods and the implementation to dimension the network.

Coverage assumption is actually one of the fundamental factors of network planning for all recent wireless technologies. Apart from this, a provider needs to ensure that sufficient QoS is maintained. Of many frequency bands in LTE, this research focuses mainly on the 1800 MHz band test network installed by Smart Mobile. Hence, motive behind this thesis and project is to study the coverage performance and limitation of LTE network on this particular band with respect to other bands.

The paper consists of five sections: I) Introduction describes the objective and approach and a short introduction tells the company's background where the paper is focused. Consequently, it also introduces the readers of the problem being addressed in this study, along with previous works and the advantage of the new radio system. II) Technical review presents the theoretical fundamentals of LTE system. Background knowledge relating to the research work. III) System design is to give a brief introduction to simulation techniques, calculation, flowchart and the data of the city. IV) Result and analysis are described in details of the system simulator. This section covers the Radio Link Budget and factors with the text explaining the method to calculate the number of sites based on the coverage and capacity. Lastly, V) Conclusions of the entire paper and suggestions the possibilities of future research and at the end, gives recommendations to the operators.

II. Technical Review

A. Long Term Evolution

The evolution from UMTS to LTE was a great step towards Broadband Wireless Communications. Because of the need for very high data rates, some of the key factors for this evolution was reduced latency, increased system capacity, bandwidth flexibility, greater coverage, seamless connectivity and reduced power consumption. To fulfill the extensive range of above requirements, many key technologies are employed in LTE. According to the research shown, bearing in mind all the spectrum requirements, data rates and performance, for the downlink, OFDMA has been agreed as the most appropriate

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technique for achieving high spectral efficiency. For the uplink, the LTE of 3GPP employs SC-FDMA because of its low Peak-To-Average Power Ratio (PAPR) properties compared to OFDMA [16]. The fundamental basic motivation for this method was to reduce power expense of the user terminal. Some of them is being used in the paper which will be outlined in the following sections.

- *Orthogonal Frequency-Division Multiple Access*

OFDM (Orthogonal Frequency Division Multiplexing) is a digital multicarrier modulation generally used in wideband communication systems. The OFDM signal can be generated by using the Fast Fourier Transform (FFT). Multicarrier means that a huge number of closely spaced sub-carriers are employed to carry the data that are divided into parallel data streams, one for each sub-carrier [18].

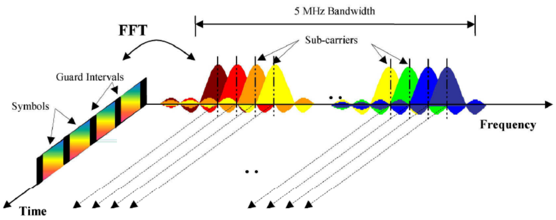


Fig. 1. Frequency-time representation of an OFDM [21]

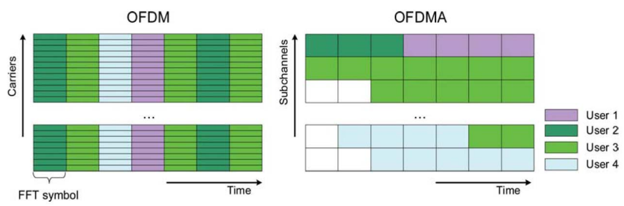


Fig. 2. Difference between channel allocation using OFDM and OFDMA scheme [15]

- *Single-Carrier Frequency-Division Multiple Access*

While OFDMA has been considered as the optimum solution for the downlink, it is less desirable for the uplink according to the weaker PAPR properties of an OFDMA signal which resulted in a worse uplink coverage. That is the main reason why the SC-FDMA is selected as the solution for the uplink. The uplink transmission scheme is specifically based on Single Carrier Frequency Division Multiple Access (SC-FDMA) because it has a lower Peak-to-Average Power Ratio (PAPR) compared to OFDM and it is a flexible modulation scheme. Low PAPR means more modest requirements for the power amplifier of UE in sense of cost and power consumption which is highly favorable in a mobile device [20]. The distinction is that in a SC-FDMA signal, the data symbols are spread over all the sub-carriers carrying information and produces a virtual single-carrier structure. As a result, if some sub-carriers are in deep fade, the information can still be recovered from other sub-carriers experiencing better channel conditions [18].

B. *Multiple Input Multiple Output*

The use of multiple antennas both at the transmitter and the receiver, which is generally referred as MIMO. An important factor to the performance of MIMO is the number of spatial layers of the wireless channel which determines the ability to improve spectral efficiency. MIMO systems introduce a spatial dimension to existing rate adaptation algorithms that implies to decide MIMO transmission type, STBC, spatial multiplexing or hybrid approaches, as well as modulation and coding type. However, in MIMO systems, correlations may occur between channel coefficients due to insufficient antenna spacing and the scattering properties of the transmission environment. This may lead to significant degradation in system performance. Mobile phone antennas are mainly used indoors in urban environments and will therefore usually exhibit strong fading due to multipath propagation [17]. Buildings, walls, cars etc. in the environment reacts the signal, so that the received signal will arrive from many directions, with different polarizations and at different times.

III. System Design

The purpose of this investigation is to understand the implications of using radio coexistence with systems of different transmission range. It also aims to compare the performance of terrestrial communication systems that use different channel assignment schemes to allocate base stations in a scenario that implements the coexistence of mixed terrestrial communication systems. To demonstrate this, the interaction and coexistence of different channel assignment schemes should be analyzed. Artificial intelligence techniques like distributed reinforcement based learning should be developed to ensure that spectrum usage is maximized.

A. *Data of Population and Map*

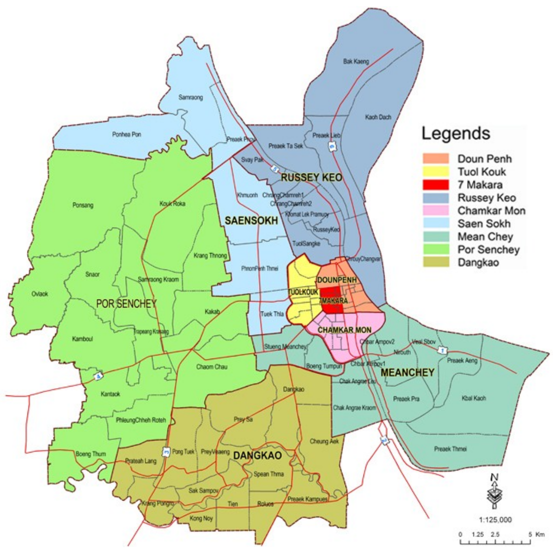


Fig. 3. Phnom Penh Map

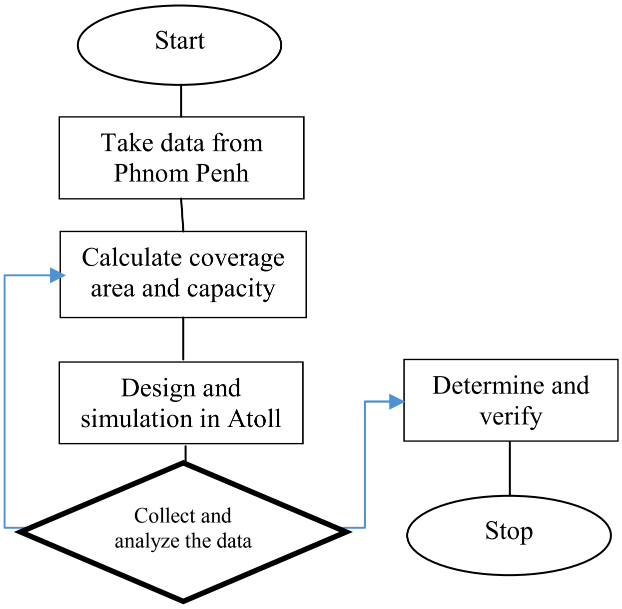
LTE downlink transmission scheme is based on Orthogonal Frequency Division Multiple Access (OFDMA) - which converts the wide-band frequency selective channel into a set of many at fading sub channels. As the topic was about

Phnom Penh city, so there are data and information that need to have such as population, grow factor, map and so on. The coverage area of the new system is 678.46 km sq. Initial data and requirement by the system configuration. The figure below is a map of Phnom Penh which contain of 9 districts. In this plan will be coverage over 9 districts but the only 4 district which are most population and in the middle of the Phnom Penh city. The table here is describe about population, area in Km^2 and density per Km^2.

TABLE I. DATA OF PEOPLE IN PHNOM PENH

District	Population	Area(Km2)	Density/Km2
7 Makara	91 895	2 228.027	44 395
ChamkaMon	182 004	10 788.213	17 468
Dangkao	69 319	117758.500	589
Doun Penh	126 550	7 412.767	17 479
Mean Chey	327 801	44 000.448	2 951
PoSenChey	183 826	230384.385	798
Russey Keo	196 684	63 948.255	1 827
Sensok	147 967	40 021.647	1 606
Toul Kork	171 200	8 432.543	21 977

B. Step Design of LTE Radio System in Phnom Penh



Flowchart 1. Step Design of LTE Radio System in Phnom Penh

LTE devices share the radio spectrum with GSM users instead of halting the current GSM services. This can be viewed as secondary access in cognitive radio regime where LTE devices as secondary users and GSM network is regarded as primary system. In the indoor are particularly interested used of LTE because more than 70% of data traffic is predicted to originate indoors by 2015.

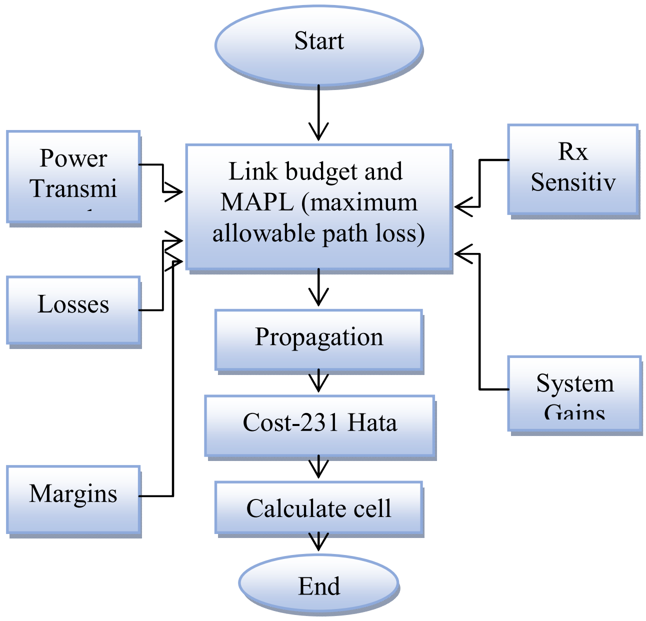
C. Calculation Coverage Area and Capacity

The link budget calculations estimate the maximum allowed signal attenuation, called path loss, between the mobile and the base station antenna. The maximum path loss allows the maximum cell range to be estimated with a suitable propagation model, such as Cost231–Hata model. The cell range gives the number of base station sites required to cover the target geographical area. The link budget calculation can also be used to compare the relative coverage of the different systems.

- *Coverage Area Calculation*

According to propagation models from HUWIA, frequency bands between 1500 MHz and 2000 MHz could use propagation model named Cost-231. And for study, frequency bands 1800 MHz was used for LTE system. Cost231-Hata model can be used in macro cells as the propagation model. The application range is as follows:

. Frequency band: 1500 MHz to 2000 MHz
. Base station height: 30 meters to 200 meters. The base station must be higher than the surrounding buildings.
. Terminal antenna height: 1 meter to 10 meters.
. Distance between the transmitter and receiver: 1 km to 20 km.



The Cost-231 Hata model provides the power path loss (PL) for an urban environment as [12]:

$$PL(d) = 46.3 + 33.9 \log (f) - 13.82 \log (Hbs) - [\, 1.1 \log (f) - 0.7 \,].Hue + [\, 1.56 \log (f) - 0.8 \,] + [\, 44.9 - 6.55 \log (Hbs) \,] . \log (d) + Cm \quad (1)$$

Where f is the center transmit frequency in MHz, d is the distance between BS and UE in Km, Hbs and Hue are BS and UE heights in meters, respectively.

f = 1800 MHz
Hbs = 30 m
Hue = 1.75
Cm = 3 dB (for metropolitan centers)
PLup = 122.8 (according to HUAWEI)
PLDown = 128

122.8 = 128.55 + 35.2248 log d
So d = 10-0.1632 = 0.68669

Cell area and total cells also need to be calculated. Here is the formula to calculate them [7].

$$Lcell = 3 \times 2.6 \times d^2 \quad (2)$$

Therefore

Lcell = 3.6780 Km2

Find the total cells

$$\sum cell = Larea / Lcell \quad (3)$$

Therefore

∑cell = 184.456

So the total cells for uplink are 185 sites.

Calculate for total cells of downlink.

128 = 128.55 + 35.2248 log d
d = 0.96468
Lcell = 7.2587 Km2
∑cell = 93.46

So the total cells for downlink are 94 sites.

- *Capacity Calculation*

A commonly accepted definition of capacity is the one provided by Shannon which states that capacity is the maximum achievable set of rates in multiple access channels with an arbitrarily small probability of error. As this metric represents a bound in performance, in practice, the sum of the transmitted data rates (downlink) or aggregated data rate is used. However, with the increased availability of new services in wireless networks, user perceived quality or QoS is now also included in many capacity measures. For instance, voice services have long been designed with a probability of error (non-connection) ranging from 1% to 3%. Capacity planning inputs gives the number of subscribers in the system, their demanded services and subscribers usage level. The population in Phnom Penh are 2,009,264 and the population growth factor is 3.921% (2008). According to these data we also can know the future population [15].

$$\text{Future population} = Po\,[(1+GF)]^n \quad (4)$$

Po = current population
GF= growth factor
N = number of forecasting years

So

$$FP = 2009264\,[(1 + 0.03921)]^{11}$$

Therefore Forecasting Phnom Penh population in 2019 is 3067422.

Productive population percentage is 64.5% = 3067422 (64.5/100) = 1978487

Market Share of Metfone is 46% = 1978487 (46/100) = 910104

LTE penetration of Metfone is 40% (assuming) = 364041

Throughput = Bearer Rate × Session Times × Session Duty Ratio × [1/(1-BLER)] (5)

Network throughput (for Dense Urban) [7]:

UL Network throughput (IP) = Total user number × UL single user throughput (6)

UL Network throughput (IP)= 364041 × 22 = 8008902 Kbps

DL Network throughput (IP) = Total user number × DL single user throughput

DL Network throughput (IP)=364041 × 44.77 = 16298115.57 kbps

Network Throughput (DL)(IP layer) = Network throughput (DL)(MAC layer) × A × B × C [7]

Network Throughput (DL) (IP layer) = 16298115.57

A × B × C = 0.98

So

Network throughput (DL) (MAC layer) = 16298115.57 / 0.98
= 16630730.17 kbps = 16630.73 Mbps

And

Network throughput (UL) (MAC layer) = 8008902 / 0.98
= 8172348.979 kbps = 8172.348.979 Mbps

Downlink Cell Capacity [19]

DL cell capacity + CRC = (168 – 36 – 12) × (code bits) × (code rate) × Nrb × C × 1000 (8)

Assumption:

Bandwidth system = 20 MHz,
MCS = 16 QAM ½, MIMO = 2 × 2, C=2
CRC = 24
168 = the number RE (resource element) in 1ms
36 = the number of control channel RE in ms
12 = the number of reference single RE in ms
4 = Code bits = modulation efficiency
½ = Code rated = channel coding rate
100 = Nrb = number of resource blocks (RBs)
2 = C = MIMO antenna mode

So

DL cell capacity = (168 – 36 – 12) × 4 × 0.5 × 100 × 2 × 1000 – 24 = 48 Mbps

Uplink Cell Capacity

UL cell capacity + CRC = (168 – 24) × (code bits) × (code rate) × Nrb × C × 1000 (9)

Assumption:

Bandwidth system = 20 MHz,
MCS = QPSK ¾ ,
MIMO = 2 × 2 , C=2
CRC = 24
168 = the number RE (resource element) in 1ms
24 = the number of reference single RE in ms
3 = Code bits = modulation efficiency
¾ = Code rated = channel coding rate
100 = Nrb = number of resource blocks (RBs)
2 = C = MIMO antenna mode

So

UL cell capacity $= (168 - 24) \times 3 \times \frac{3}{4} \times 100 \times 2 \times 1000 - 24$
$= 43.2$ Mbps

Site Calculation

Number of site = Network throughput / Site capacity [3.10]

Number of siteDL = 16298115.57 / 48 = 339.5

So

Number of siteDL = 340 sites

And

Number of siteUL = 8008902 / 43.2 = 185.391

So

Number of siteUL = 186 sites

IV. Result and Analysis

Map is the first thing that need to have for LTE system map planning. Here is the location of a base station in the Phnom Penh City. According to that table data there are around 257 sites in Phone Penh City. The figure here is the area which will be design for and figure 4 is the table of data sites in the Software, it also show the latitude and longitude.

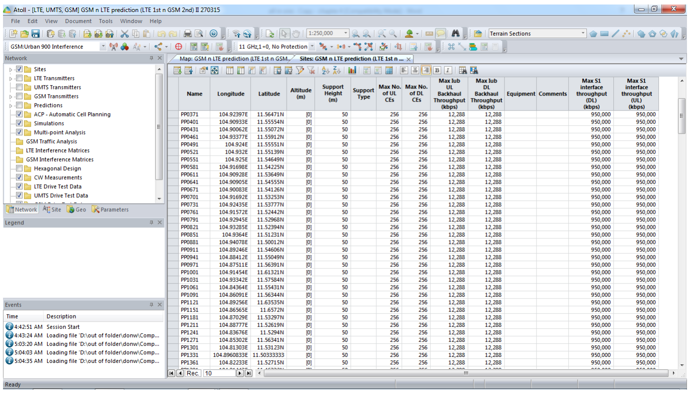


Fig. 4. Map of position site in Phnom Penh City

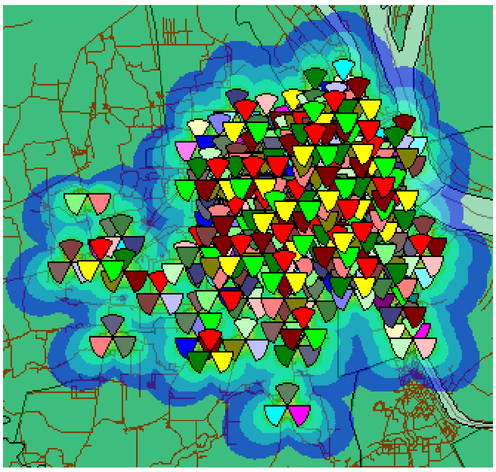


Fig. 5. Coverage by signal level

As the calculation result in section III, in the LTE coverage area calculation are 185 sites which is be able to coverage in central Phnom Penh. There was few prediction types which was chosen to analyses and simulation such as coverage by throughput and overlapping zones.

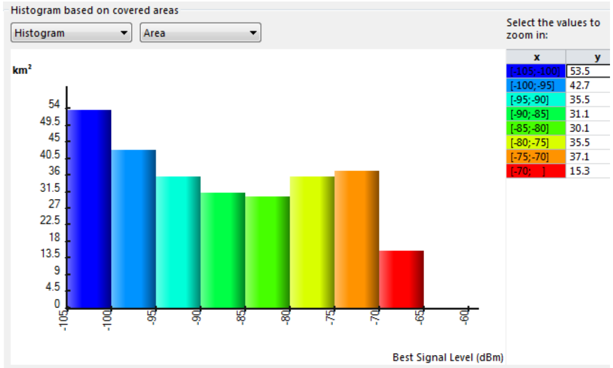


Fig. 6. Diagram of Coverage by signal level in Area

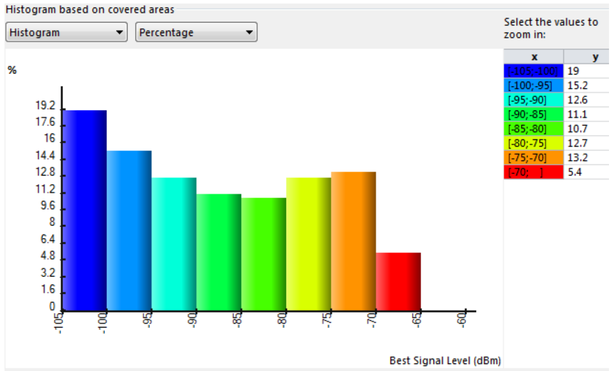


Fig. 7. Diagram of Coverage by signal level in Percentage

Here is the simulation of coverage by signal level. As we see in the figure above, there are 185 sites in central Phnom Penh which work with LTE system.

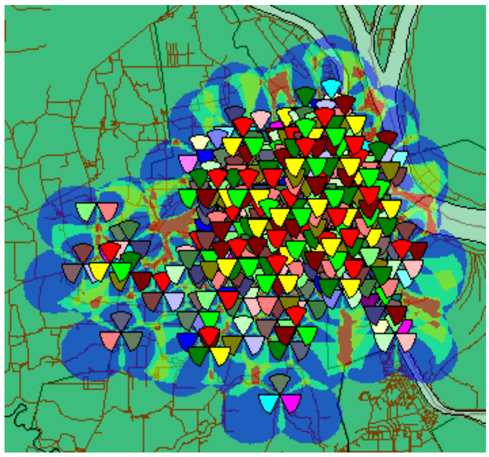


Fig. 8. Coverage by overlapping zones

There are two king of the histogram, are and percentage. The sample of coverage by signal level be able to cover area of 53.3 Km2. That was the best signal level of -105dBm until -100dBm and the minimum coverage is 15.3 Km^2 for -70dBm till -65dBm. Other figure is the histogram of coverage area by percentage which 19% of a simple is the maximum and 5.4% is minimum. Overlapping zone in this simulation are 280.8 Km^2 and the computation zone area in the software platform are 298.08 km^2, so the blank spot are 17.28 km^2. According to the histogram of the overlapping zone, it can say that the operator or severs were serve enough services in the city. The figure below show that, 1 or 2 severs can be overlapping up to 165.9 Km^2 and 4 until 5 server also overlap about 31.1Km^2.

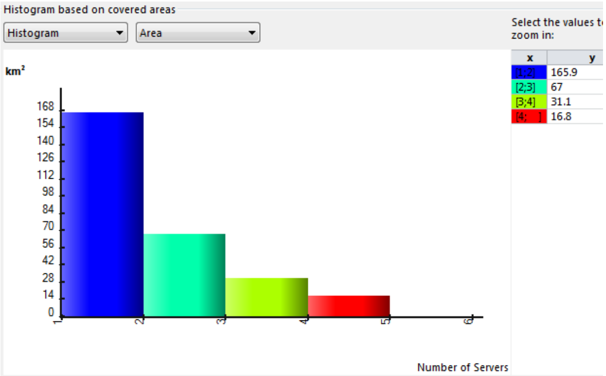


Fig. 9. Coverage by overlapping zone in Area

Actually not only coverage by overlapping zones that can show in the Google Earth, other kind of the prediction also can be there. Because of the view and the coverage is similar after exported so they were not appear for all in this paper.

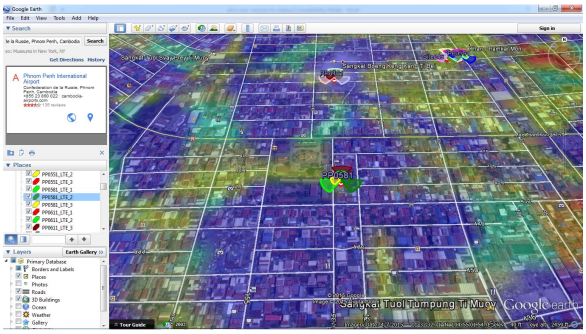


Fig. 10. Overlapping Zone show in Google Earth

V. Conclusion

To maintain its competitive edge in the world of mobile networks in the future, 3GPP has initiated work on LTE. The growing popularity of innovative mobile technologies is coming together with trends showing high predominance of data networks. It means that consumer demand for data services is increasing and nowadays, the penetration of smart-phones, tablets and other data devices as well as the launching of 4G/LTE service reflects the high levels of data traffic carried on mobile networks. This work was cover around 678.43 km^2 and it was about coverage by single level and the overlapping zone. According to the simulation result for the software platform the overlapping zone be able to cover up to 60 percent. This is good enough for the requirement for Phnom Penh city need.

The work done in this study covers the access network dimensioning of LTE network. The capacity of the LTE network is depicted with the indicators of average transmission data rate, peak transmission data rate and the area supported by the system. The coverage of the LTE system is also calculated on the base of Base Station parameters. Moreover, the unavailability of reliable LTE network simulators is a big hurdle in full calibration of this tool. Currently, the simulation results for only a limited antenna and in the city. Using a more accurate simulator will yield better results for capacity planning exercise.

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